31. *The Acid Hydrolysis of Methyl 2,3-Anhydro-D-hexopyranosides.*

By J. G. Buchanan and J. Conn.

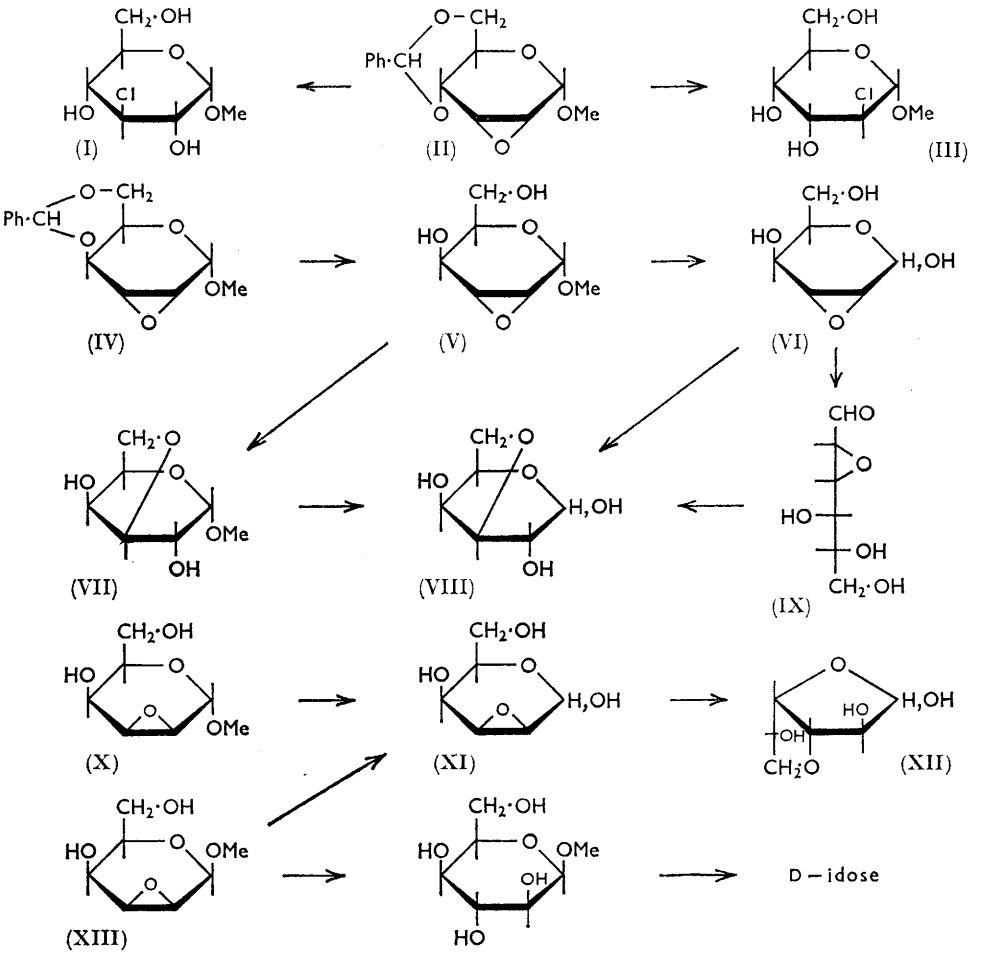
3,6-Anhydrohexoses are major reaction products when a number of methyl 2,3-anhydrohexopyranosides are subjected to hydrolysis with 0·1N-sulphuric acid. Possible reaction sequences are discussed. 3,6-Anhydro-5-*O*-benzoyl-1,2-*O*-isopropylidene-β-L-idose results from treatment of 3,6-anhydro-1,2-*O*-isopropylidene-5-*O*-toluene-*p*-sulphonyl-α-D-glucose with sodium benzoate in dimethylformamide.

Reaction between sugar vicinal epoxides and aqueous hydrochloric acid is known, in many cases, to yield chlorohydrins.[1–7] Methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-alloside (II), for example, gives a mixture of the two *trans*-products, methyl 3-chloro-3-deoxy-α-D-glucoside (I) and methyl 2-chloro-2-deoxy-α-D-altroside (III) in which the glucose isomer predominates.[3] The behaviour of the same anhydro-sugar towards aqueous sulphuric acid has been examined [3] and methyl α-D-glucoside isolated from the mixture. Dilute sulphuric acid behaves normally with methyl 3,4-anhydro-α- and -β-D-galactoside [7,8] giving the expected *trans*-products, D-gulose and D-glucose. However, the action of dilute sulphuric acid on some methyl 2,3-anhydro-glycosides yields, in addition, a 3,6-anhydrohexose, sometimes as the major product.[9] A similar result was obtained independently by Dekker and Hashizume [10] in the case of 5,6-anhydro-1,2-*O*-isopropylidene-α-D-glucofuranose, which gives D-glucose and 2,5-anhydro-L-idose on hydrolysis. We now present a more detailed account of our findings.

Initially it was observed that methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-guloside (IV), when treated with 0·1N-sulphuric acid, gave only a trace of the "normal" idose and galactose derivatives. The major product was a reducing sugar which streaked badly on paper chromatograms, a property of 3,6-anhydrogalactose (VIII).[11] On subsequent treatment with phenylhydrazine, 3,6-anhydro-D-galactosazone [12] was isolated. Clearly, intramolecular attack by the 6-hydroxyl group on the 2,3-epoxide ring had occurred. The actual sequence of reactions may follow two courses (A or B). In either case, hydrolysis of the *O*-benzylidene group occurs first to give the anhydro-glycoside (V).[13] This may undergo intramolecular reaction to the 3,6-anhydrogalactoside (VII) by analogy with similar reactions under alkaline conditions (route A); [14–16] acid hydrolysis to the free sugar (VIII) would then occur very rapidly.[12] Alternatively, acid hydrolysis of the glycoside (V) to the anhydrogulose (VI) may occur, with subsequent formation of 3,6-anhydrogalactose (VIII) (route B); if the latter mechanism is operating, there are several analogies [10,17–20] suggesting that the acyclic form (IX) of 2,3-anhydro-D-gulose may be an intermediate.

1 Müller, *Ber.*, 1934, **67**, 421.
2 Robertson and Dunlop, *J.*, 1938, 472.
3 Newth, Overend, and Wiggins, *J.*, 1947, 10.
4 Newth and Homer, *J.*, 1953, 989.
5 Labaton and Newth, *J.*, 1953, 992.
6 Buchanan, *J.*, 1958, 995.
7 Buchanan, *J.*, 1958, 2511.
8 Müller, *Ber.*, 1935, **68**, 1094.
9 Buchanan, *Chem. and Ind.*, 1958, 654.
10 Dekker and Hashizume, *Arch. Biochem. Biophys.*, 1958, **78**, 348.
11 Clingman, Nunn, and Stephen, *J.*, 1957, 197.
12 Haworth, Jackson, and Smith, *J.*, 1940, 620.
13 Bolliger and Reichstein, *Helv. Chim. Acta*, 1953, **36**, 302.
14 Peat, *Adv. Carbohydrate Chem.*, 1946, **2**, 37.
15 Foster, Stacey, and Vardheim, *Acta Chem. Scand.*, 1958, **12**, 1819.
16 Lemieux and Barrette, *J. Amer. Chem. Soc.*, 1958, **80**, 2243.
17 Vargha and Puskas, *Ber.*, 1943, **76**, 859.
18 Wiggins and Wood, *J.*, 1950, 1566.
19 Ross, *J.*, 1950, 2257.
20 Vargha and Kasztreiner, *Chem. Ber.*, 1960, **93**, 1608.

It was decided to study a 2,3-anhydro-glycoside which could not react by route A. Suitable compounds are the methyl 2,3-anhydro-D-talopyranosides (X) and (XIII). In these compounds the vicinal epoxide ring is *cis* to the hydroxymethyl group and no intramolecular cyclisation can occur until the glycosidic linkage has been hydrolysed. Crystalline methyl 2,3-anhydro-α-D-taloside (X) was prepared by mild acid hydrolysis of methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-taloside.[21] The corresponding β-anomer (XIII) was prepared essentially according to Wiggins's method.[22] When each was hydrolysed under the same conditions with 0·1N-sulphuric acid at 100° the α-compound was not detectable after 30 minutes, whereas the β-compound required nearly 3 hours for complete hydrolysis. Chromatograms of the hydrolysates showed that 3,6-anhydroidose was the major product



from the α-anomer, together with a little idose; from the β-anomer, 3,6-anhydroidose was the major product, but an appreciable quantity of idose was also present, together with a trace of galactose. On a preparative scale, 3,6-anhydro-D-idose (XII) was identified as the 1,2-*O*-isopropylidene derivative, and D-idose was converted into D-iditol hexa-acetate. These experiments show that 3,6-anhydro-D-idose is produced from the anhydrotalosides (X) and (XIII). Since this cannot take place by route (A), reaction must proceed by

[21] Sorkin and Reichstein, *Helv. Chim. Acta*, 1945, **28**, 1.
[22] Wiggins, *J.*, 1944, 522.

route (B), *i.e.*, by an intramolecular reaction of 2,3-anhydro-D-talose (XI). In this particular example, the formation of the 3,6-anhydro-ring could involve the acyclic or the furanose form of 2,3-anhydro-D-talose. It is interesting that no 2,3-anhydrotalose could be detected chromatographically during the course of reaction; it appears that the hydrolysis of the glycoside linkage in the 2,3-anhydro-glycoside is the rate-controlling step in this case.

We have examined the reaction between methyl 2,3-anhydro-α-D-alloside [2,23] (XIV) and 0·1N-sulphuric acid at 100°. Paper chromatography after a hydrolysis time of 2 hours showed 3,6-anhydroglucose (XVIII), methyl glucoside, methyl altroside, altrose, and unchanged starting material. Methyl α-D-glucoside, which had been obtained by previous workers,[3] was isolated in 21% yield, 3,6-anhydro-D-glucose in 13% yield, and methyl α-D-altroside (as the tetra-acetate) in 3% yield. These figures are isolated yields and give only an approximate idea of the relative amounts of products. When the hydrolysis of methyl 2,3-anhydro-4,6-*O*-benzylidene-β-D-alloside [24] was compared with that of methyl 2,3-anhydro-α-D-alloside (XIV) by paper chromatography, the rate of disappearance of 2,3-anhydro-β-D-alloside (XVI) was about four times that of the α-anomer. Furthermore, the major product from the β-anomer was 3,6-anhydroglucose. As in the anhydroguloside case the reaction can, in theory, proceed either by way of 2,3-anhydro-D-allose (XV) (route B) or through the 3,6-anhydro-D-glucopyranosides (XVII) or (XIX) (route A).

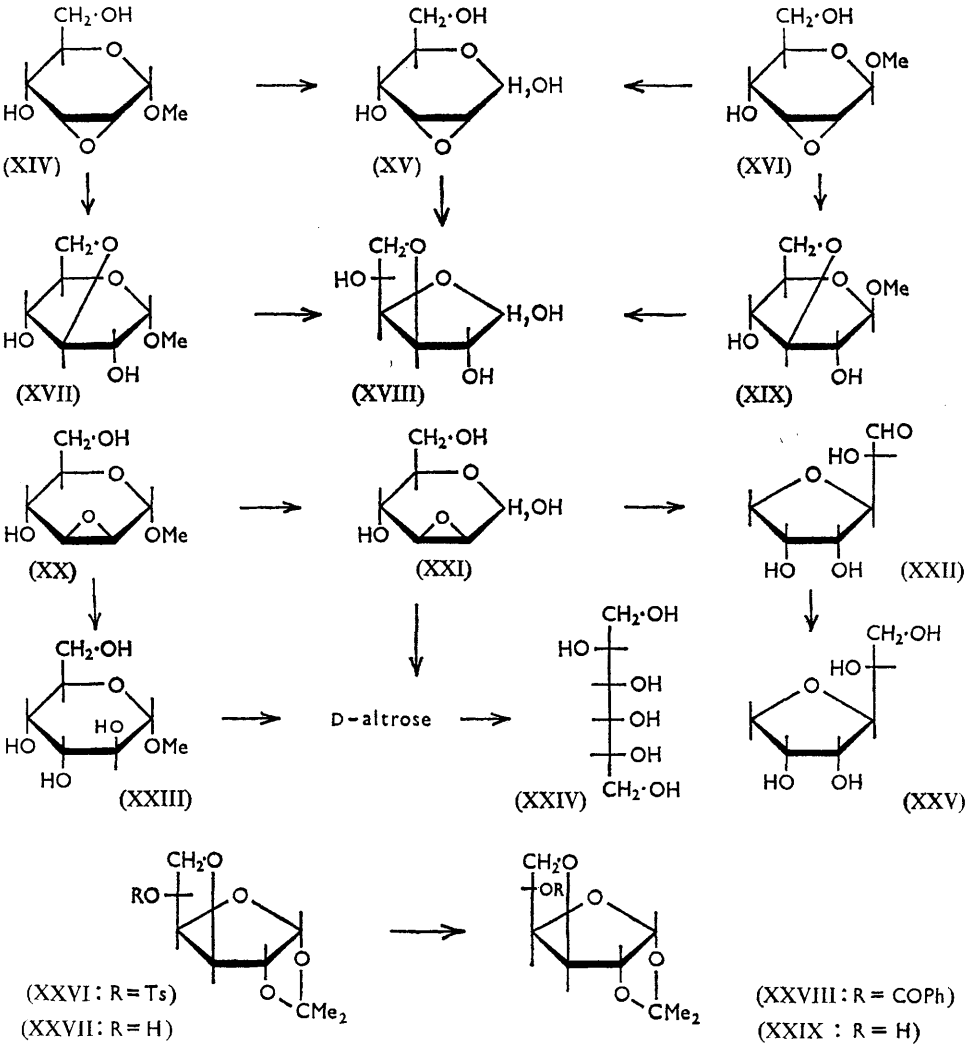
Lastly in this series, the behaviour of methyl 2,3-anhydro-α-D-mannoside (XX) [25,26] was studied. After 30 minutes' hydrolysis with 0·1N-sulphuric acid at 100°, most of the starting material had disappeared. The products detected by paper chromatography were methyl altroside, altrose, and two others of some interest; no methyl glucoside was present, in agreement with other work on the direction of acidic ring-opening in the anhydromannoside (XX).[4] Of the two unknown products, one had the properties of 2,3-anhydro-D-mannose (XXI); it had a lower R_F value than the starting material and reacted with aniline phthalate [27] (reducing sugar) and with sodium iodide–Methyl Red reagent [26] (vicinal epoxide). This is the only 2,3-anhydro-hexose we have found which is fairly stable under acidic conditions. The other unknown product streaked badly on chromatograms, giving a yellow colour with periodate–Schiff's reagent [28] and a red colour with aniline phthalate. This compound was also present after 2 hours' hydrolysis, when all the 2,3-anhydromannose had disappeared. It was formed, together with altrose, when some of the 2,3-anhydromannose was isolated from a paper chromatogram and subjected to further hydrolysis.

Borohydride reduction of the crude hydrolysis mixture caused disappearance of any compound reacting with aniline phthalate, and there were three major products detectable by paper chromatography. These were separated by chromatography on thick paper. Crystalline D-altritol (D-talitol) (XXIV), derived from D-altrose in the original hydrolysate, was isolated. Methyl α-D-altroside (XXIII) was isolated as its crystalline tetra-acetate. The third compound behaved like an anhydro-hexitol on paper chromatograms, and was identical in its chromatographic behaviour to the major product from acid dehydration of D-altritol.[29] In a separate experiment the products after borohydride reduction were fractionated by chromatography on Dowex 1 (OH) resin; [30] D-altritol was again isolated and the suspected anhydro-hexitol was shown to be 3,6-anhydro-D-altritol (1,4-anhydro-D-talitol) by conversion into its crystalline di-*O*-isopropylidene compound.[31] We thank Dr. A. B. Foster for supplying details of this compound prior to publication. We also

[23] Gut and Prins, *Helv. Chim. Acta*, 1947, **30**, 1223.
[24] Peat and Wiggins, *J.*, 1938, 1088.
[25] Jeanloz and Jeanloz, *J. Amer. Chem. Soc.*, 1958, **80**, 5692.
[26] Buchanan and Schwarz, *J.*, 1962, 4770.
[27] Partridge, *Nature*, 1949, **164**, 443.
[28] Hardy and Buchanan, *J.*, 1963, 5881.
[29] Baddiley, Buchanan, and Carss, *J.*, 1957, 4138.
[30] Austin, Hardy, Buchanan, and Baddiley, *J.*, 1963, 5350.
[31] Brimacombe, Evans, Foster, and Webber, *J.*, 1964, 2735.

used this derivative to show that 3,6-anhydro-D-altritol is a product of acid dehydration of D-altritol.[29]

The 3,6-anhydro-D-altritol (XXV) must clearly arise from 3,6-anhydro-D-altrose (XXII) by borohydride reduction. As Foster [32] pointed out, 3,6-anhydroaltrose cannot exist in a



pyranose-ring form, and equally it cannot exist as a furanose. It is not surprising, then, that it should streak badly on a paper chromatogram (cf. 3,6-anhydrogalactose [11]) and give a yellow colour with periodate–Schiff's reagent.[28] It appears that the 2,3-anhydromannoside (XX) is hydrolysed in two ways; partly to give methyl α-D-altroside (XXIII), which is then slowly converted into D-altrose, and partly to give 2,3-anhydro-D-mannose (XXI), which may form D-altrose or 3,6-anhydro-D-altrose (XXII). In many ways this is the most interesting case of the behaviour of a 2,3-anhydro-hexoside towards dilute sulphuric acid; the 2,3-anhydro-hexose can be detected chromatographically as an intermediate; it yields, necessarily by way of its acyclic form, a 3,6-anhydro-aldehydo-sugar.

[32] Foster, *J.*, 1957, 2833.

For reference purposes a sample of 3,6-anhydroidose was required. 3,6-Anhydro-1,2-*O*-isopropylidene-β-L-idose (XXIX) has been described by Ohle and Lichtenstein,[33] but it was decided to prepare it by a different method. When 3,6-anhydro-1,2-*O*-isopropylidene-5-*O*-toluene-*p*-sulphonyl-α-D-glucose (XXVI) is treated with alkali, sulphur–oxygen fission occurs and 3,6-anhydro-1,2-*O*-isopropylidene-α-D-glucose (XXVII) results.[34] As Mills [35] pointed out, the sulphonate (XXVI) is an *endo*-compound and by analogy with the dianhydro-hexitols [35] it should be possible to cause inversion at C-5.[36] The sulphonate (XXVI) was heated with sodium benzoate in dimethylformamide [37] to give the crystalline benzoate (XXVIII). Debenzoylation gave the 3,6-anhydro-L-idose derivative (XXIX) whose physical constants agreed with those previously reported.[33] The product obtained from hydrolysis of the 2,3-anhydro-D-talosides was the enantiomorph.

Experimental

Infrared spectra were measured for potassium bromide discs. Melting points are uncorrected. Light petroleum refers to the fraction of b. p. 40—60°. Comparison of materials with authentic substances was made, unless stated otherwise, by mixed m. p. determinations and infrared spectra.

Chromatographic Methods.—Adsorption chromatography was carried out on silica gel (Messrs. Hopkin and Williams). Paper chromatography was carried out on Whatman no. 1 paper with the following solvent systems: (A) butan-1-ol–pyridine–water (3 : 1 : 1, v/v); (B) butan-2-one saturated with water, the chromatogram being pre-equilibrated for a few hours before running. Reducing sugars were detected by using aniline phthalate,[27] α-glycols with periodate–Schiff's reagent,[28] and vicinal epoxides with the sodium iodide–Methyl Red reagent.[26]

Hydrolysis of Methyl 2,3-Anhydro-4,6-O-benzylidene-α-D-gulosides with 0·1N-Sulphuric Acid.—(*a*) The glycoside [21] (a few mg.) was hydrolysed in a sealed tube at 100° for 1 hr. and the product examined by paper chromatography in solvent A. Traces of galactose, idose, and methyl idoside were present. The main product was a streak giving a brown colour with aniline phthalate and a yellow colour with periodate–Schiff's reagent, identical with that from an authentic sample of 3,6-anhydro-D-galactose.

(*b*) The glycoside (0·5 g.) and 0·1N-sulphuric acid (10 c.c.) were heated on a steam-bath for 1·5 hr. After cooling, the liquid was extracted with ether and to the aqueous fraction was added acetic acid (2 c.c.), anhydrous sodium acetate (0·75 g.), and phenylhydrazine hydrochloride (0·9 g.). After 30 min. at 100° the preparation was cooled and left overnight at 0°. The precipitate was filtered and washed with water, 2N-acetic acid, and a little methanol. The yellow crystals (0·12 g.) had m. p. 213—215° and an infrared spectrum identical to that of authentic 3,6-anhydro-D-galactosazone,[12] m. p. 214°.

2,3-Anhydrotalosides.—Methyl 2,3-anhydro-α-D-taloside. Methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-taloside [21] (1·0 g.) was heated under reflux with aqueous sulphuric acid (0·01N; 20 c.c.) and methanol (6 c.c.) for 30 min. according to Gut and Prins.[23] The *anhydrotaloside* crystallised from ethanol as needles (0·59 g., 88%), m. p. 128—129°, $[\alpha]_D^{18}$ +13·9° (*c* 4·53 in H_2O) (Found: C, 47·7; H, 7·0. $C_7H_{12}O_5$ requires C, 47·7; H, 6·8%).

Methyl 2,3-anhydro-β-D-talopyranoside. Methyl 2-*O*-toluene-*p*-sulphonyl-β-D-galactoside [38] (2·48 g.) was suspended in water (10 c.c.) and phenolphthalein (1 drop) added. N-Sodium hydroxide was added dropwise to the boiling suspension until a permanent pink colour was obtained.[39] The solution was evaporated to dryness and the residue extracted with hot ethyl acetate. The extract was evaporated and a chloroform solution of the residue chromatographed on silica (20 g.). Chloroform and chloroform–ethanol (19 : 1) eluted fractions which crystallised from ether to give the anhydro-compound (1·05 g., 84%), m. p. 103—105° (lit.,[22] 103—104°).

Comparison of Hydrolysis of Anhydrotalosides by 0·1N-Sulphuric Acid.—The anhydrotalosides (8 mg.) were each dissolved in a few drops of 0·1N-sulphuric acid and samples heated in sealed

[33] Ohle and Lichtenstein, *Ber.*, 1930, **63**, 2905.
[34] Ohle, Vargha, and Erlbach, *Ber.*, 1928, **61**, 1211.
[35] Mills, *Adv. Carbohydrate Chem.*, 1955, **10**, 1.
[36] Wolfrom, Bernsmann, and Horton, *J. Org. Chem.*, 1962, **27**, 4505.
[37] Reist, Spencer, and Baker, *J. Org. Chem.*, 1959, **24**, 1618.
[38] Bacon, Bell, and Kosterlitz, *J.*, 1939, 1248.
[39] Charalambous and Percival, *J.*, 1954, 2443.

tubes at 100° for various periods. The products were examined by paper chromatography in solvent A using the sodium iodide–Methyl Red and aniline phthalate reagents. The results are quoted in the main discussion.

Hydrolysis of Methyl 2,3-*Anhydro*-α-D-*taloside*.—The anhydro-compound (0·207 g.) in 0·1N-sulphuric acid (5 c.c.) was heated on a water-bath at 100° for 30 min. The solution was neutralised ($BaCO_3$), filtered, and the filtrate evaporated to a syrup which was shaken with acetone (100 c.c.) containing concentrated sulphuric acid (0·5 c.c.) for 30 min. The solution was neutralised with solid sodium carbonate (10 g.) overnight. The filtered solution was evaporated and the residue repeatedly recrystallised from benzene to give 3,6-anhydro-1,2-*O*-isopropylidene-β-D-idofuranose (0·16 g., 67%), m. p. 102—103°, $[\alpha]_D^{23}$ −24·0° (*c* 1·36 in H_2O). The infrared spectrum was identical to that of the L-isomer (see below).

Hydrolysis of Methyl 2,3-*Anhydro*-β-D-*taloside*.—The anhydro-compound (0·5 g.) in 0·1N-sulphuric acid (5 c.c.) was heated on a water-bath at 100° for 3 hr. The solution was neutralised ($BaCO_3$), filtered, and the filtrate evaporated to a syrup which was chromatographed as a band on a sheet of Whatman No. 3 paper in solvent A. The idose and 3,6-anhydroidose bands were cut out, eluted with water, and evaporated to syrups which were treated as follows. (i) The idose syrup (0·145 g., 28%) was dissolved in water (10 c.c.), sodium borohydride (0·04 g.) added, and the solution set aside overnight. Dilute acetic acid was added, sodium ions removed on a Dowex 50 (H^+) column, and the eluate evaporated to dryness. Boric acid was removed by treatment of the residue with methanol followed by evaporation (4 times), and the product acetylated with acetic anhydride and pyridine. The acetate (0·19 g.) was isolated using chloroform, and had m. p. 123—124° (from ethanol), $[\alpha]_D^{18}$ +22·3° (*c* 2·53 in $CHCl_3$). The infrared spectrum of the product was identical with that of an authentic sample of L-iditol hexa-acetate, $[\alpha]_D^{19}$ −26·1° (*c* 0·92 in $CHCl_3$), kindly provided by Professor T. Reichstein. (ii) The 3,6-anhydroidose syrup (0·19 g., 41%) was converted into 3,6-anhydro-1,2-*O*-isopropylidene-β-D-idofuranose (0·16 g., 68%), m. p. 105—106°, $[\alpha]_D^{21}$ −24·7° (*c* 0·66 in H_2O) in the same way as above.

2,3-*Anhydroallosides*.—*Comparison of hydrolysis of anhydroallosides by* 0·1N-*sulphuric acid*. Methyl 2,3-anhydro-4,6-*O*-benzylidene-β-D-alloside [24] and methyl 2,3-anhydro-α-D-alloside [23] were hydrolysed with 0·1N-sulphuric acid at 100° under comparable conditions. After 75 min. no methyl 2,3-anhydro-β-D-alloside was detectable by the sodium iodide–Methyl Red reagent [26] after paper chromatography. A trace of the α-anomer was present after 275 min. From the β-anomer, the major product was 3,6-anhydroglucose, with smaller amounts of methyl glucoside and methyl altroside.

Hydrolysis of methyl 2,3-*anhydro*-α-D-*allopyranoside*. The anhydro-sugar [23] (0·5 g.) and aqueous sulphuric acid (0·1N; 5 c.c.) were heated under reflux for 2 hr. on a boiling water-bath. The cooled solution was neutralised ($BaCO_3$), filtered, and evaporated to a syrup which was examined by paper chromatography in solvent B. Together with starting material, there were detected methyl glucoside, methyl altroside, altrose, 3,6-anhydroglucose, and glucose (a trace). The syrup crystallised from a little ethanol to give methyl α-D-glucopyranoside (0·115 g., 21%) m. p. 167—168°. The remaining product was fractionated on a large sheet of Whatman No. 3 paper using solvent B. (i) The 3,6-anhydroglucose band was eluted with water, the sugar crystallised from methanol, and recrystallised from acetone to give small needles (0·06 g., 13%), m. p. 120—121°, $[\alpha]_D^{21}$ +52·2° (*c* 1·02 in H_2O) (lit.,[34] m. p. 119°, $[\alpha]_D$ +55·39°). The infrared spectrum was identical with that of an authentic sample. (ii) The methyl altroside band was eluted with water and the residue after evaporation acetylated with acetic anhydride and pyridine. The acetate (0·026 g., 3%), m. p. 88—89° (from ether–light petroleum), was identical with an authentic sample of methyl α-D-altropyranoside tetra-acetate.[40]

Hydrolysis of Methyl 2,3-*Anhydro*-α-D-*mannoside with* 0·1N-*Sulphuric Acid*.—(*a*) The anhydromannoside [26] (a few mg.) was hydrolysed in sealed tubes at 100° for 30, 60, and 90 min. and the products examined by chromatography in solvent A. After 30 min. only a trace of starting material remained and it was undetectable thereafter. 2,3-Anhydromannose, reacting with aniline phthalate and with sodium iodide–Methyl Red, was present but after 90 min. had almost disappeared. Altrose and methyl altroside were present in all samples. One product streaked badly, giving a red colour with aniline phthalate and a yellow colour [28] with periodate–Schiff's reagent; this was probably 3,6-anhydroaltrose.

(*b*) The anhydromannoside (0·25 g.) in 0·1N-sulphuric acid (5 c.c.) was heated at 100° for

[40] Richtmyer and Hudson, *J. Amer. Chem. Soc.*, 1941, **63**, 1727.

2¼ hr. The solution was neutralised ($BaCO_3$), filtered, and evaporated to a syrup which was dissolved in water and treated with sodium borohydride (0·05 g.) at room temperature overnight. The solution was acidified with acetic acid and sodium ions removed by a short column of Dowex 50 (H^+) resin. The eluate was evaporated to dryness and boric acid removed by distillation with four portions of methanol. The syrupy residue was subjected to chromatography on Whatman No. 3 paper using solvent A. The methyl α-D-altroside band was eluted with water and characterised as the tetra-acetate (0·06 g., 12%), m. p. 88—90°, identical with an authentic sample.[40] The D-altritol was eluted with water and crystallised from ethanol. The hexitol (0·08 g., 31%) had m. p. 87—89°, and was identical with an authentic sample. The 3,6-anhydro-D-altritol was eluted with water and attempts made to obtain a crystalline derivative. The anhydro-hexitol did not crystallise, nor did the acetate or benzoate. The chromatographic behaviour of the anhydro-hexitol was indistinguishable from that of the major product of acid treatment of altritol [29] (see below).

(*c*) The anhydromannoside (0·65 g.) in 0·1N-sulphuric acid (10 c.c.) was heated under reflux for 2·5 hr. and then neutralised ($BaCO_3$). Paper chromatography showed no vicinal epoxide and showed that altrose, methyl altroside, and 3,6-anhydroaltrose were the products; 1,6-anhydroaltrose has the same R_F value as altrose. The filtered solution was treated with sodium borohydride (0·25 g.) for 20 hr. at room temperature, and the syrupy product isolated as in (*b*) above. Paper chromatography showed that reducing sugars were absent and that altritol, 1,6-anhydroaltrose, 3,6-anhydroaltritol, and methyl altroside were present. About half was dissolved in water (1 c.c.) and chromatographed on a column (30 × 1 cm.) of Dowex 1 × 2 (OH^-) resin.[30] Elution was with water and fractions of 5 c.c. were collected. Fractions 15—25 gave D-altritol (0·06 g.) which crystallised from ethanol and was identical with an authentic sample. Fractions 10—13 contained chromatographically pure 3,6-anhydro-D-altritol. Evaporation gave a syrup (0·02 g.) which was treated with acetone (10 c.c.) containing concentrated sulphuric acid (0·1 c.c.) for 21 hr. at room temperature. The solution was poured into water (10 c.c.) containing sodium carbonate (1 g.) and the mixture extracted with chloroform (2 × 15 c.c.). The extract was dried (Na_2SO_4) and evaporated to a syrup (0·02 g.) which crystallised on nucleation. It was purified by vacuum sublimation and then had m. p. 48°, $[\alpha]_D^{22}$ −36° (*c* 0·38 in $CHCl_3$). It was identical with an authentic sample of 3,6-anhydro-1,2:4,5-di-*O*-isopropylidene-D-altritol (1,4-anhydro-2,3:5,6-di-*O*-isopropylidene-D-talitol).[31]

Treatment of D-*Altritol with Acid.*—D-Altritol (0·23 g.) was heated with 2N-sulphuric acid (2 c.c.) in a sealed tube at 100° for 3 days. It was neutralised ($BaCO_3$), evaporated to a syrup (0·18 g.), and examined by paper chromatography in solvent A. Besides unchanged altritol (R_F 0·20) there were three products of R_F values 0·31, 0·41, and 0·47.[29] The major product, R_F 0·31, gave a yellow colour, changing to blue, with periodate–Schiff's reagent, consistent with it being 3,6-anhydro-D-altritol.[28] The product, R_F 0·41, gave a blue colour slowly with these reagents and was probably a 2,5- or 1,5-anhydro-hexitol. The product, R_F 0·47, present in small amount, gave a purple colour rapidly with these reagents and was probably 1,4-anhydro-D-altritol. The syrupy product was dissolved in water (1 c.c.) and chromatographed on Dowex 1 × 2 (OH^-) resin (30 cm. × 1 cm.).[30] Water eluted first the 3,6-anhydroaltritol, followed by altritol and the two other products. 3,6-Anhydro-D-altritol (0·02 g.) was converted into its di-*O*-isopropylidene derivative as described above. The diketal (0·02 g.), m. p. 49—50°, was identical with an authentic sample; [31] acid hydrolysis (0·1N-sulphuric acid at room temperature for 24 hr.) gave 3,6-anhydro-D-altritol, R_F 0·31 in solvent A.

3,6-*Anhydro*-5-O-*benzoyl*-1,2-O-*isopropylidene*-β-L-*idofuranose*.—3,6-Anhydro-1,2-*O*-isopropylidene-5-*O*-toluene-*p*-sulphonyl-α-D-glucose (0·5 g.), sodium benzoate (1·0 g.), and dimethylformamide (15 c.c.) were heated under reflux for 9 hr. After cooling, water (15 c.c.) was added and the crystalline product filtered and washed with water, to give needles (0·36 g., 84%), m. p. 83—84° (from methanol), $[\alpha]_D^{18}$ +78·8° (*c* 2·01 in $CHCl_3$) (Found: C, 63·1; H, 5·8. $C_{16}H_{18}O_6$ requires C, 62·8; H, 5·9%). The infrared spectrum showed a strong peak at 1724 $cm.^{-1}$ (aromatic ester C:O) and no sulphonate ester peaks at 1189 or 1176 $cm.^{-1}$.

3,6-*Anhydro*-1,2-O-*isopropylidene*-β-L-*idofuranose*.—The above benzoate (0·2 g.) was debenzoylated with sodium methoxide in methanol (5 c.c.). The solution was neutralised (CO_2) and evaporated to dryness. The residue was extracted with hot benzene from which the product crystallised on partial evaporation (0·1 g., 76%), m. p. 105—107°, $[\alpha]_D^{18}$ +28·2° (*c* 0·90 in H_2O) (lit.,[33] m. p. 105°, $[\alpha]_D$ +24·9°) (Found: C, 53·5; H, 7·2. Calc. for $C_9H_{14}O_5$: C, 53·7; H, 7·0%).

When a mixture of equal quantities of the D- and L-isomer was recrystallised from benzene a racemate, m. p. 72—74°, was obtained.

We thank the Council of King's College (now the University) for the award of the Johnston Studentship (to J. C.) and Dr. A. B. Foster for a sample of 1,4-anhydro-2,3:5,6-di-*O*-isopropylidene-D-talitol.

DEPARTMENT OF ORGANIC CHEMISTRY,
THE UNIVERSITY, NEWCASTLE UPON TYNE 1. [*Received, April 29th,* 1964.]